than it is in the complete structure, because in the former case the slab can expand freely, whereas in the other case this lateral expansion is prevented.

If some portion of the total load was taken by the dam acting as a horizontal beam, this claim would not be challenged by me, but Prof. Pearson states that his proposition is true independent of any action of this character. On a question of pure mathematics it is no doubt very rash for a mere engineer to differ from Prof. Pearson, but as the point is of great practical importance I make the venture, since the statement appears to me to be opposed to the mathematical theory of elasticity as usually taught. The sole difference between the two cases lies in the fact that when the slab constitutes a portion of a complete dam it is subject to a certain normal stress which Prof. Pearson calls $\widehat{yy}$.

Now the characteristic of this stress is that it produces no appreciable shear in planes parallel to itself or in planes at right angles to itself. In fact, Prof. Pearson states that in both cases we may put $\widehat{yx} = \widehat{yz} = 0$, and that $\widehat{xz}$ is identically the same in both cases.

Consider, then, the slab, taking first the case in which the sides are left free to expand, but in which stresses are produced in it due to the water pressure and its own weight. Taking $\widehat{xx}$ as the stress parallel to the horizon and $\widehat{zz}$ as that parallel to the weight, we have, Prof. Pearson says, the following equations which these must satisfy :—

$$\frac{\partial}{\partial x} \cdot \widehat{xx} + \frac{\partial}{\partial z}\widehat{xz} = 0$$

$$\frac{\partial}{\partial x} \cdot \widehat{xz} + \frac{\partial}{\partial z} \cdot \widehat{zz} + \rho g = 0.$$

Under these internal stresses the sides of the slab undergo a displacement $v = f(xz)$, say. This displacement, it should be noted, is everywhere finite and continuous.

Now apply, to the slab, forces $\widehat{yy} = F(xz)$, so distributed as to cancel the above displacement, and we get the conditions of the equilibrium when the slab forms part of a complete dam.

Next consider these forces $\widehat{yy} = F(xz)$ to act alone. The characteristic of the internal stress then produced is, as already pointed out, that $\widehat{yx} = \widehat{yz} = \widehat{zx} = 0$, so that the conditions of internal equilibrium reduce to

$$\frac{\partial}{\partial x} \cdot \widehat{xx} = 0$$

$$\frac{\partial}{\partial y} \cdot \widehat{yy} = 0$$

$$\frac{\partial}{\partial z} \cdot \widehat{zz} = 0.$$

These and the boundary conditions are obviously satisfied by putting $\widehat{xx} = \widehat{zz} = 0$ and $\widehat{yy} = F(xz)$ throughout. If, at the same time, the conditions of continuity are satisfied, this should be the solution. It would seem that the continuity of the material is necessarily satisfied by the fact that v, the displacement of the surface under the forces, is everywhere finite and continuous. If I am right in this, the stresses $\widehat{xx}$ and $\widehat{zz}$ should be the same in the complete dam as they are in the slab, but Prof. Pearson says this is not the case.　　　　H. M. MARTIN.

Croydon, December 22, 1907.

LORD KELVIN: AN APPRECIATION.

LORD KELVIN occupied for a long time a unique and cosmopolitan position as the universally venerated head of the physical science of the age. Where he did not himself create new knowledge, he constantly inspired discovery. Always accessible, always keenly attracted by the work of others and ready to learn, with universal interests, and mental activities untiring even to the end, he for more than half a century was the main practical scientific influence in this country; while for the latter portion of this period his point of view, through the generous

advocacy of Helmholtz and other fellow-workers, became naturalised throughout the world. He was representative, more. than any other person, of the combination of abstract scientific advance and mechanical invention which led to the still recent electrical transformation of modern engineering; he sustained and elevated industrial progress by the fire of intellectual genius.

In his earliest scientific work he was the interpreter of Faraday, at a time when support and mathematical elucidation of the intuitions of his genius were much required. In addition to special advances of his own into new domains, such as the theoretical prediction of electric vibrators and their laws forty years before they were utilised by Hertz, and the assertion of the thermochemical principles controlling voltaic batteries, he early became the founder, or rather restorer, of a school—the modern British school of physical science—which aims at moulding the course of general physical theories, even of abstract mathematics itself, by aid of intuitions drawn from exact formulation of the observed course of nature, assisted by illustrations such as may be gleaned even from the study of artificial practical mechanisms. A typical example of this kind of activity was the vortex theory of the molecular structure of matter, which he built on Helmholtz's fundamental discovery of the absolute permanence of vortical motions in a frictionless fluid medium; to a superficial view this is now in the main only an abandoned theory; but those most conversant with the history of the coordination of physical activities, which is the ultimate aim of the science, will allow that the vortex-atom theory was the first illustration that included any adequate idea of the type of interaction of the material atoms and the universal æther in which they subsist, and as such has been the direct ancestor of all subsequent advances towards the mental representation of ultimate physical reality.

In particular Lord Kelvin was the inspirer of Clerk Maxwell, his avowed pupil in all important respects, and was thereby an essential factor in that consolidation and reconstruction of physical science, on a refined electric, or subelectric, basis, which is still in progress, and has been a main glory of recent years.

In another region of his activity he combined delicate mathematical methods of investigation with broad industrial application of the results. It was largely the determined and prolonged struggle to carry through to success the enterprise of Atlantic submarine telegraphy that led to the invention of those appliances for exact measurement which afterwards made general electrical engineering feasible. In this new branch of applied science, his active perception of the essentials for progress assumed the form of generalship; most of the details of development naturally came from others, but he was always ready to emphasise the salient problems, and to acclaim, early and enthusiastically, such nascent inventions as would be pertinent to their mastery.

An example of his firm grasp of the connection of theory and practice is afforded by his work on the prediction of the tides. The recognition that the tidal oscillation is compounded of a limited number of simple harmonic constituents, of known periods, was an outgrowth of physical astronomy, and is mainly due to Laplace; the principle that any oscillatory movement arising from permanent causes is resolvable into simple harmonic constituents, and is to be treated on that basis in all exact science, was the fundamental contribution of Fourier. It remained largely for Lord Kelvin to combine these two principles, supplying the mechanical contrivances necessary for rapid computation, and thereby to control all that is requisite to be known about the tides. while avoiding the complexi-

ties, arising from the irregular forms of the oceans, that would choke any attempt at direct dynamical calculation in detail. Other examples of the same faculty are afforded by his fundamental improvements in ships' compasses and in deep-sea sounding; while his life-long work on problems relating to the speed of ships, the waves they produce and the energy lost in their formation, has been a chief influence in the rational study of the conditions and limitations of marine propulsion.

He will be known to future ages, possibly even more widely, as a main pioneer and creator in the all-embracing science of energy, the greatest physical generalisation of the last century. He was the first to grasp and insist on the universal dynamical, even cosmical, importance of the principle of reversible cyclic processes, which sprang almost in advance of its time from the genius of Carnot. Concurrently with Clausius he soon supplied the necessary logical adjustment of its thermal application; and by his own work, and his collaboration with Joule, he largely constructed the practical essentials of the fundamental, because unifying, modern science of thermodynamics. The depth and generality of the conceptions, which pervade his fragmentary and often hurried writings on this subject, have been recognised sometimes only after the same ideas have been slowly evolved afresh, and acclaimed in their varied applications as advances of the first rank, on the part of other investigators.

In Lord Kelvin there has passed away one of the last commanding figures, perhaps in genius and the variety of his activities as great and memorable as any, in the scientific and intellectual development of the nineteenth century. J. L.

LORD KELVIN AND THE UNIVERSITY OF GLASGOW.

AT a college meeting in 1891, Sir William Thomson said :—" I have been a student of the University of Glasgow fifty-five years to-day, and I hope to continue a student of the University as long as I live." In 1899, when he retired from the professorship which he had held for fifty-three years, Lord Kelvin (as he had then become) applied to the Senatus Academicus to be appointed a research student. His name thus remained to the last upon the College roll, and in the list of those who have a right to pursue investigations in the laboratories of natural philosophy.

An academic connection so long, so intimate, and so fruitful is not severed without a deep sense of personal bereavement on the part of the survivors. The university, of which, since 1904, Lord Kelvin was the venerated head, was plunged into deep mourning by the news of his death. Special meetings of the court and senate, and of the executive of the general council, were held, and passed minutes of regret and sympathy. The regular classes were suspended; the courts were silent; the flag that usually waves high over the Kelvin drooped at half-mast. The new institute of natural philosophy which the Chancellor, at its opening in April last, took such pride in displaying to the Prince and Princess of Wales, was closed; and throughout the city, which regards the university's glories as its own, the signs of mourning were everywhere visible. Telegrams and messages from local public bodies, learned societies, and representative men, arrived hourly at Gilmorehill. The note of admiring affection for a great fellow-citizen was prominent in these, for Lord Kelvin was a freeman of the city, and a leader in its technical enterprises, no less than a teacher and investigator in the university. Hence came about a certain wistful acquiescence, on the part of Glasgow men, in the arrangement whereby

he was to be laid to rest beside his intellectual peers in Westminster Abbey. The national tribute was felt to be right and fitting; though not a few were hoping that his burying-place would be in the City Necropolis, where his father and others of his kindred are laid.

In order that expression might be given to the *genius loci,* a memorial service was held by the university in the Bute Hall on Sunday afternoon, December 22, simultaneously with that held at Largs before the funeral company started on their journey southward with Lord Kelvin's body. The hall, which serves as the university chapel, was draped with black, and filled with a congregation of nearly two thousand mourners. All stood, as to the strains of the Dead March the long academic procession, representing the court, senate and other teachers, general council, and students, preceded by the ancient mace swathed in crape, filed in and occupied the stalls and platform. Many of the congregation wore the graduate's robe, and students, men and women alike, wore their undergraduate gowns of scarlet. The Vice-Chancellor, Principal MacAlister, presided, and read the lessons (Job 28, and 1 Corinthians 15) from his stall. The simple service of prayer and praise was conducted by two professors of the faculty of divinity (Drs. Reid and Cooper), and was marked by devout resignation, and by thanksgiving for a great example, rather than by the gloom of unrelieved mourning. The anthem Nunc Dimittis, sung by the university voluntary choir, and a special prayer for the university, that in it all science and scholarship might be consecrated to the honour of God and the promotion of human welfare, gave the characteristic notes. There was no sermon or funeral discourse; this will more fittingly be given hereafter. The venerable Lord Blythswood, the Lord Provost, Sir William Bilsland, the president of the faculty of physicians and surgeons, Admiral Bearcroft, Dr. William Wallace, Dr. George Neilson, and many other men of note in the west of Scotland were present. Relatives and others connected with the Chancellor's family, and the officials of the electrical manufacturing firm of Kelvin and White, which he founded, occupied seats near the daïs. The funeral march of Chopin closed the ceremony, as the university procession passed out of the hall into the darkness of the winter afternoon, and the silence of the courts that the Chancellor had loved so well.

Telegrams of condolence with the university were received during the week from Mr. Marconi, Glacé Bay; the University of London; University College, Nottingham; the Duke of Argyll, representing His Majesty the King; the Faculty of Science of the University of Rome: Prof. Egoroff, director of the Central Chamber of Weights and Measures, St. Petersburg; Principal Voinarowsky, of the St. Petersburg Electrotechnical Institute; the Chancellor of the Exchequer, Lord Rector of the University; Sir James King, Bt., Dean of Faculties; Rector Borgman, of the Imperial University of St. Petersburg; the Russian Physico-chemical Society; Rector Syniewski and professors of the Polish Technical College, Lvov; Rector Bagatcy and professors of the University of Charkow; Rector de Mbinski and Senate of the University of Lemberg; the Royal College of Surgeons of Edinburgh; the Senatus of the U.F. Theological College, Aberdeen; the students of physics of the University of St. Petersburg; President Dini, and the Faculty of Science of the University of Pisa; the University of Liverpool; the Ambassador of France; the Senatus of the University of Aberdeen; the St. Petersburg Society of Electrical Engineers; the pro-rector and professors of the University of Jurjew (Dorpat); &c.